

ELECTRONIC FUNDAMENTALS

EXPERIMENT LESSON 10

MAGNETIC EXPERIMENTS



RCA INSTITUTES, INC.

**A SERVICE OF RADIO CORPORATION OF AMERICA
HOME STUDY SCHOOL**

350 West 4th Street, New York 14, N. Y.

Experiment Lesson 10

PART ONE

OBJECT

The object of the experiments in Part One of this lesson is to learn:

That a magnet attracts certain materials and not others.

How the lines of force are distributed.

How the lines of force are distributed between the poles of a bar magnet.

That the direction of the lines of force may be observed.

How two bar magnets affect each other.

How the shape of a magnet affects the density of the field.

How magnetic material can be used as a magnetic shield.

That some materials are magnetically transparent.

PREPARATION

Study Theory Lesson 10, *Magnetism and Electromagnetism*.

INFORMATION

In this experiment lesson, you are going to work some simple experiments with magnets. What you learn from these experiments, and from Theory Lesson 10, *Magnetism and Electromagnetism*, will be interesting in itself. However, even more important is the fact that what you learn about the principles of magnetism will be of great importance to

your understanding of radio and TV.

You have learned from your study of the theory of magnets that magnets attract and repel because of the lines of force between their poles. In the following experiments, we are going to work with these lines of force in different ways.

EQUIPMENT NEEDED

Two bar magnets

Horseshoe magnet

Iron filings

Sheet of paper

Sheet of cardboard

Three small iron or steel nails

Compass

Copper penny

Dime

Brass screw

Small steel or iron tacks

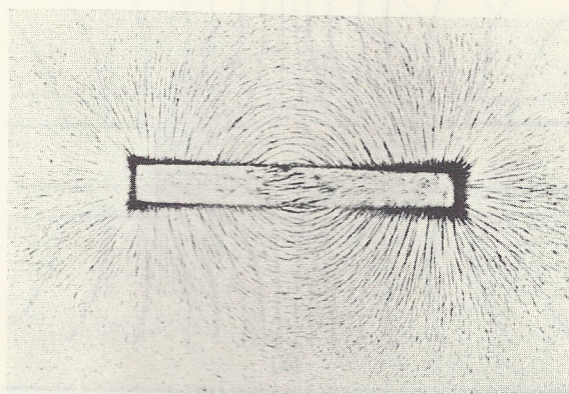
EXPERIMENT 10-1

To try to attract various materials with a bar magnet.

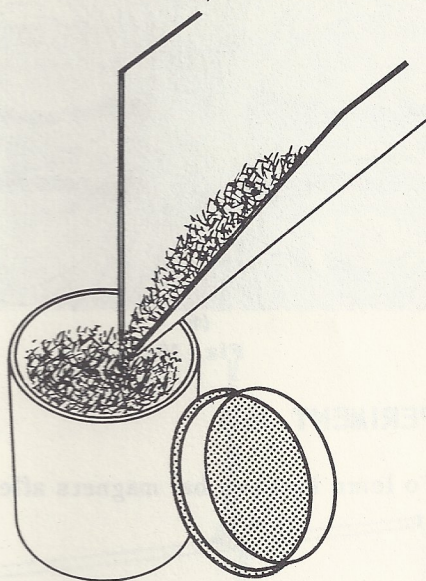
Procedure.

Step 1. Place a small iron nail on the table and bring the bar magnet close to it. Remove the nail from the magnet.

Step 2. Place the copper penny on the table and bring the magnet close to it. The magnet will not attract the penny.



(a)



(b)

Fig. 10-1

Step 3. Place the dime on the table and bring the magnet close to it. The magnet will not attract the dime.

Step 4. Place the brass screw on the table and bring the magnet close to it. The magnet will not attract the screw.

Discussion. From the experiment you just performed, you were able to see that a magnet will attract some materials and not others. The nail is made of a magnetic material, and so the magnet attracted it. The other objects you tried to attract with the magnet are made of non-magnetic materials, and so the magnet did not attract them. From this experiment, you can see that a simple test of whether or not a material is magnetic is to try to attract it with a magnet.

EXPERIMENT 10-2

To see the path of the lines of force between the poles of a bar magnet.

Procedure.

Step 1. Place the bar magnet long-side down on the table.

Step 2. Place a piece of cardboard on top of the magnet and a piece of paper on top of the cardboard. The magnet should be under the center of the cardboard.

Step 3. Lightly sprinkle some iron filings on the sheet of paper. Tap the paper. The filings will arrange themselves in the pattern shown in Fig. 10-1a. The paths made by the filings are the paths of the lines of force between the poles of the magnet.

Step 4. Carefully pick up the paper and pour the filings back into the container, as shown in Fig. 10-1b.

Discussion. In this experiment, you were able to observe the effect on the iron filings of the lines of force between the poles of a bar magnet. You were able to see that the filings were concentrated at the poles of the magnet; therefore, you proved that the lines of force are most concentrated at the poles of the magnet. You were able to notice the form of the lines of force between the north and south poles. Be sure you understand exactly what you have proved in this experiment before you go on to the other experiments. If necessary, go back to Theory Lesson 10, *Magnetism and Electromagnetism*, and re-read the material that will help you to understand this experiment.

EXPERIMENT 10-3

To observe the direction of the lines of force between the poles of a bar magnet.

Procedure.

Step 1. Place a compass next to the

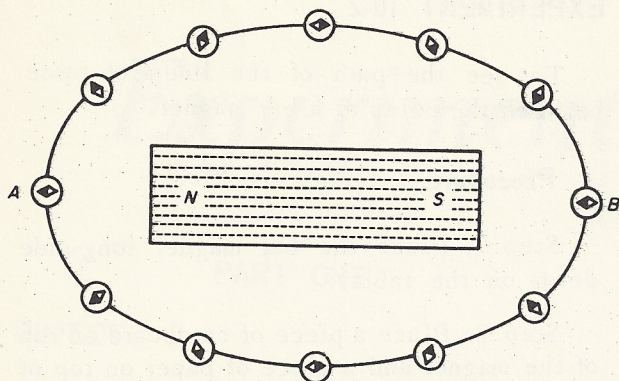


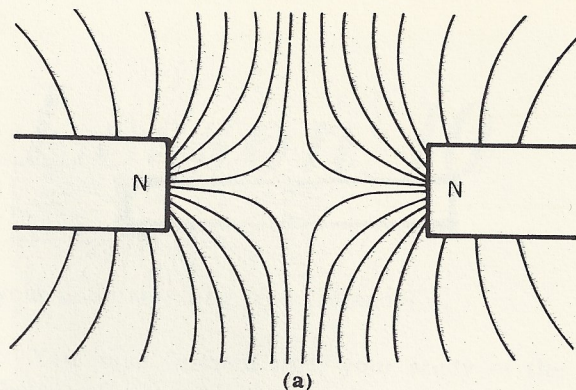
Fig. 10-2

north pole of the bar magnet, as shown in position A of Fig. 10-2. With the compass in this position, the compass needle will be deflected as shown in the figure. (If the needle points in the opposite direction, the compass is at the south pole of the magnet and should be moved to the north pole.)

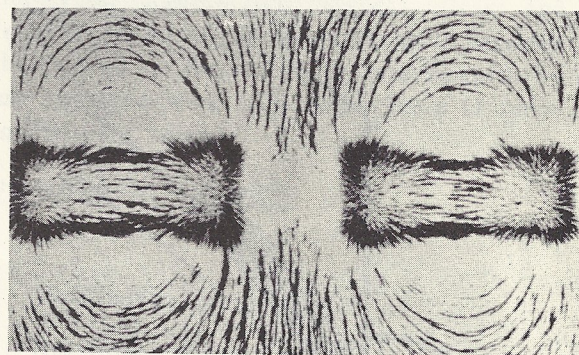
Step 2. Move the compass along the path shown in the figure toward the south pole. Observe the deflection of the needle as the compass is moved. The needle will point in the direction of the lines of force, from the north pole to the south pole of the magnet, as shown in Fig. 10-2. When the compass reaches position B, the needle will be pointing toward the south pole, as shown in the figure.

Step 3. Move the compass along the other side of the magnet from the south pole to the north pole. Observe the deflection of the needle of the compass. Once more, the needle will point in the direction of the lines of force between the two poles of the magnet, as shown in Fig. 10-2.

Discussion. The deflection of the compass needle is caused by the lines of force that form the magnetic field of the magnet. The deflection of the needle is in the same direction as the lines of force. Therefore, the compass needle always points in the direction of the lines of force, and the compass can be used to determine the direction of the lines of force. It is important to understand this point.



(a)



(b)

Fig. 10-3

EXPERIMENT 10-4

To learn how two bar magnets affect each other.

Procedure.

Step 1. Place two bar magnets on the table, with the north pole of one facing the north pole of the other, as shown in Fig. 10-3a.

Step 2. Cover the magnets with a sheet of cardboard, and cover the cardboard with a sheet of paper.

Step 3. Lightly sprinkle iron filings on the paper. Observe the pattern that the filings form. If the pattern you see does not look similar to the pattern shown in Fig. 10-3b, tap the paper lightly.

Step 4. Remove the cardboard and paper from the magnets and pour the iron filings back into the can.

Step 5. Place the two bar magnets with

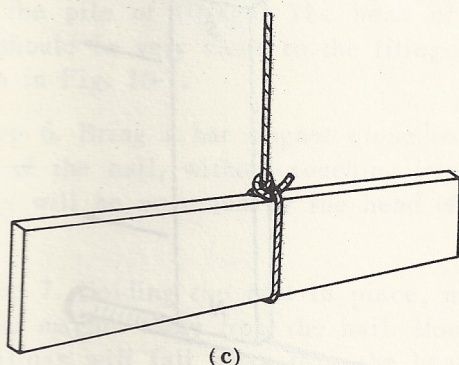
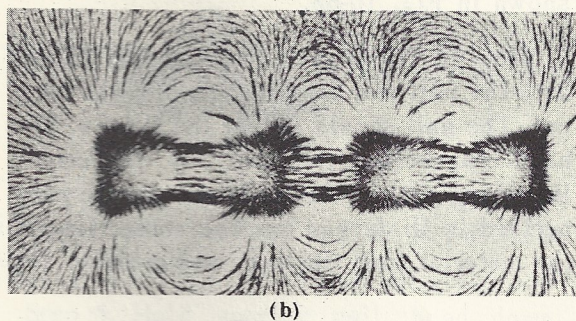
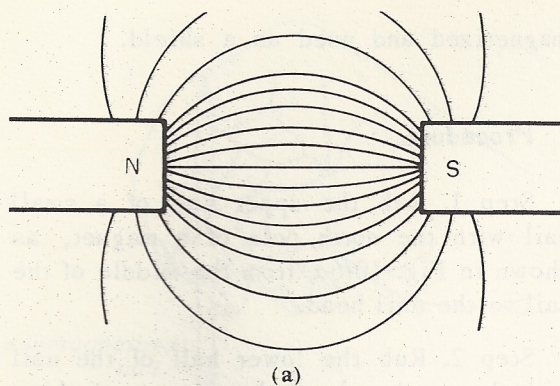


Fig. 10-4

the north pole of one facing the south pole of the other, as shown in Fig. 10-4a. Repeat the operations in Steps 2 and 3. The filing pattern should look like the one shown in Fig. 10-4b. Notice that the lines of force around each magnet look much like the lines of force around the magnet in Experiment 10-2. Note that the lines of force about the two facing poles are much straighter.

Step 6. Tie a string around the center of the bar magnets, as shown in Fig. 10-4c. Hold the string between the fingers of one of your hands. Wait for the magnet to stop

swinging and turning. Look at your compass and notice which way is north. The north pole of your suspended bar magnet will also point north. Bring the north pole of the other magnet close to the north pole of the suspended magnet. Notice that the suspended magnet is repelled by the magnet you bring close to it.

Step 7. Repeat Step 6 with the north pole of the suspended magnet facing the south pole of the other magnet. The magnets are attracted to each other. After you remove the other magnet and the suspended magnet comes to rest, notice that the north pole of the suspended magnet again points to the earth's north pole.

Discussion. When similar poles of two bar magnets face each other, the lines of force of one magnet repel the lines of force of the other magnet. You noticed that when these similar poles are brought together, one magnet repels the other. You were able to see that when opposite poles of two bar magnets face each other, the lines of force reinforce one another. As a matter of fact, the two bar magnets tend to have a pattern of lines very similar to the field of force of a single bar magnet. When opposite poles of two bar magnets are brought close to each other, the magnets are attracted to each other.

Therefore, you have proved that when the lines of force oppose, there is repulsion. When the lines of force reinforce one another, there is attraction. So, you can see how very important it is to know which poles of a pair of magnets you are dealing with when you are trying to produce attraction or repulsion.

You noticed too that, when the suspended magnet stopped swinging and there was no other magnet near, it pointed north. The north pole of a free-swinging magnet always points north. This is one way by which we can tell the north pole of a magnet.

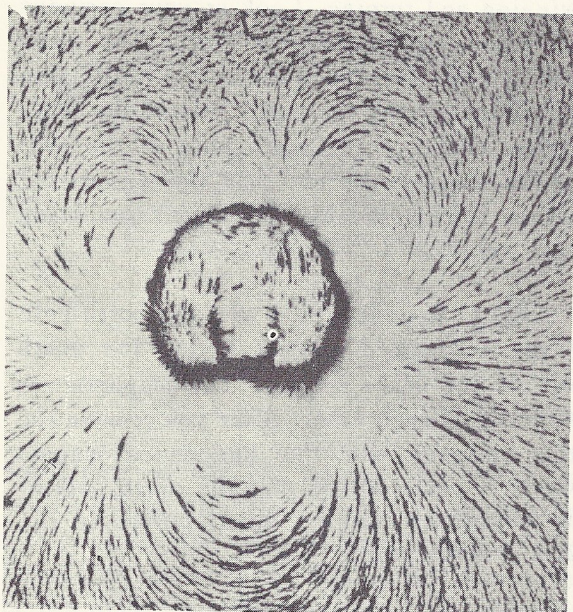


Fig. 10-5

EXPERIMENT 10-5

To see the pattern of the lines of force between the poles of a horseshoe magnet.

Procedure.

Step 1. Place the horseshoe magnet on the table and place a piece of cardboard and a sheet of paper over it.

Step 2. Sprinkle iron filings over the paper and observe the pattern the iron filings make. If the pattern you see does not look like the pattern in Fig. 10-5, tap the paper lightly.

Step 3. Remove the paper and cardboard and pour the iron filings back into the can.

Discussion. You saw that the lines of force are concentrated between the poles of the horseshoe magnet. Because the poles are close together, it is easier for lines of force to form. So, there are more of them. As you learned in Theory Lesson 10, the closer the poles, the stronger is the magnetic field.

EXPERIMENT 10-6

To learn how magnetic material can be

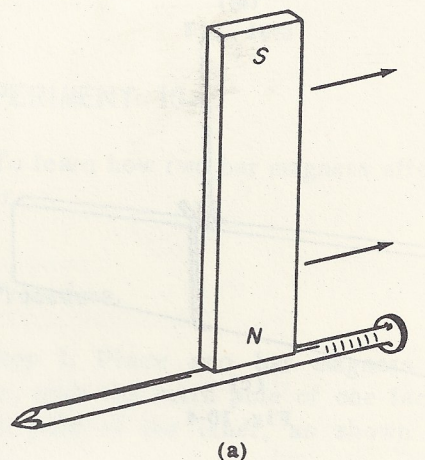
magnetized and used as a shield.

Procedure.

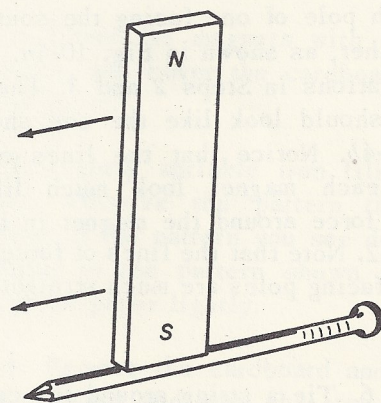
Step 1. Rub the upper half of a small nail with the north pole of a magnet, as shown in Fig. 10-6a, from the middle of the nail to the nail head.

Step 2. Rub the lower half of the nail with the south pole of the magnet, stroking from the middle of the nail to the tip, as shown in Fig. 10-6b.

Step 3. Try to pick up some iron filings with the nail you have rubbed with the magnet. The nail should attract the filings. You have magnetized the nail by induction. How long a time the nail will remain magnetized will depend on the retentivity of the material from which it was made.



(a)



(b)

Fig. 10-6

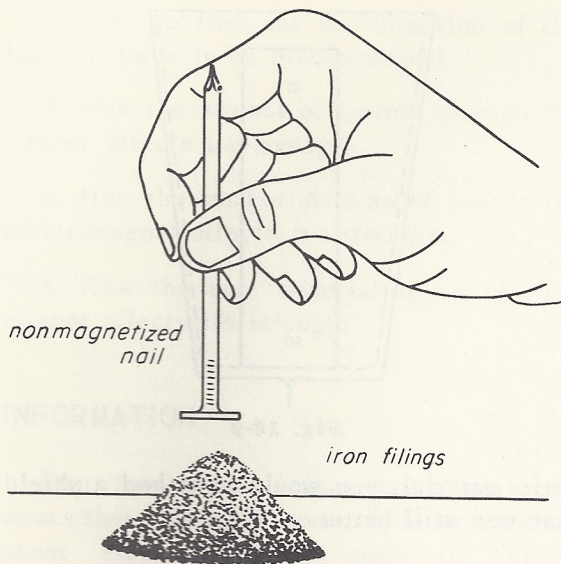


Fig. 10-7

Step 4. Sprinkle some iron filings in a little pile on a piece of paper and place the paper on the table.

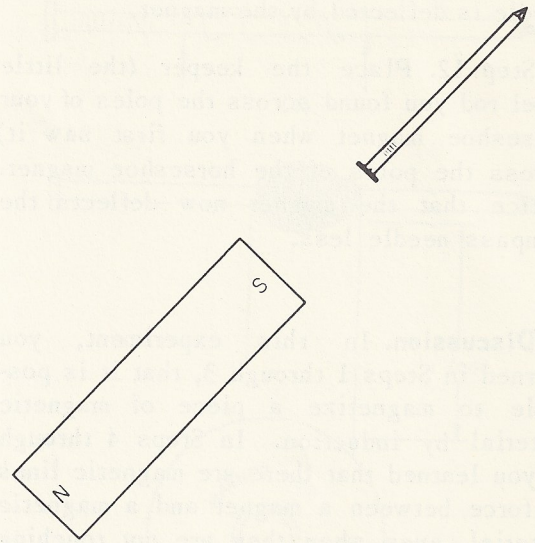
Step 5. Hold another nail, head down, over the pile of filings. The head of the nail should be very close to the filings, as shown in Fig. 10-7.

Step 6. Bring a bar magnet close to the point of the nail, without touching it. The filings will be attracted by the head of the nail.

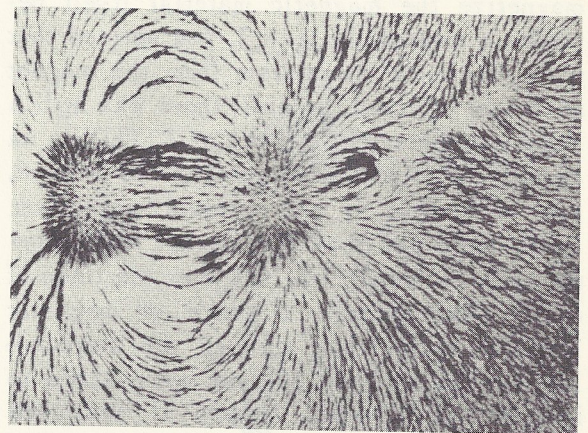
Step 7. Holding the nail in place, move the bar magnet away from the nail. Most of the filings will fall away from the head of nail. Wipe off the filings that still stick to the head of the nail.

Step 8. Hold another nail over the pile of iron filings. Touch the nail with a bar magnet. The filings will be attracted to the head of the nail. Move the bar magnet away from the nail. Most of the filings will fall away from the head of the nail. Wipe the rest of the filings off the nail.

Step 9. Place the magnet and nail on the table with the nail just far enough away from the magnet so that it is not attracted by the magnet, as shown in Fig. 10-8a. Cover the magnet and the nail with a sheet of cardboard and a sheet of paper. Sprinkle from filings on the paper and observe the



(a)



(b)

Fig. 10-8

pattern the filings make. You will see that the lines of force do not go directly from one pole of the magnet, but are deflected through the nail, as shown in Fig. 10-8b. The nail provides a better path for the magnetic lines of force than the air; that is, the steel nail offers less *reluctance* to the lines of force than air does. Pour the filings back in the can.

Step 10. Imagine that you were able to surround the bar magnet with such nails. The magnetic lines of force would then travel from one pole of the magnet, around the low-reluctance path provided by the nails, and to the other pole of the magnet.

Step 11. Place your horseshoe magnet on the table. Place your compass on the table near the magnet. Observe that the compass

needle is deflected by the magnet.

Step 12. Place the keeper (the little steel rod you found across the poles of your horseshoe magnet when you first saw it) across the poles of the horseshoe magnet. Notice that the magnet now deflects the compass needle less.

Discussion. In this experiment, you learned in Steps 1 through 3, that it is possible to magnetize a piece of magnetic material by induction. In Steps 4 through 6, you learned that there are magnetic lines of force between a magnet and a magnetic material, even when they are not touching each other, and that these lines of force magnetize the magnetic material itself becomes a magnet. In Step 7, you noticed that even when the magnetism from the magnet no longer affected the nail, there was still a little magnetism left in the nail. This is an example of residual magnetism. In Step 8, you were able to see residual magnetism again when you took the magnet away from the nail. In Step 9, you saw how the lines of force pass through a piece of magnetic material rather than through the surrounding air. So, in Step 10, you were asked to imagine what would happen if you used a circle of iron nails placed around the magnet to provide a path of low reluctance for the lines of force. You were able to see that, if you provided such a path, you could guide the lines of force so that they would be in the path you provided. If it is possible to guide lines of force as you choose, then of course it is possible to keep them away from places where you do not want them. In Steps 10 and 11 you used the keeper to provide a path for the lines of force between the poles of your horseshoe magnet. By providing this path, you reduced the effect of the magnet on the compass. Thus, you shielded the compass from the magnet. Of course, your shield was not perfect. If you had been able to put your magnet in a box made of soft iron, the shielding would have been better. And, if you had been able to put that box inside another soft iron box and had been able to keep the two boxes separated by a nonmag-

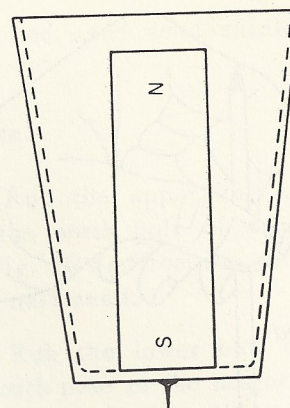


Fig. 10-9

netic material, you would have had a shield that was still better.

EXPERIMENT 10-7

To see that some materials have so little effect upon the passage of magnetic lines of force that we can speak of them as being magnetically transparent.

Procedure.

Step 1. Place one bar magnet in a water glass.

Step 2. Place a tack on the table.

Step 3. Hold the glass with the magnet in it over the tack. The tack will be attracted by the magnet and will stick to the bottom of the glass, as shown in Fig. 10-9.

Step 4. Remove the magnet and put it in an aluminum pot. Hold the pot over the tack and observe that the tack is attracted to the bottom of the pot, where the magnet is.

PART TWO

OBJECT

The object of the experiments in Part Two of this lesson is to learn:

1. How to find out the direction of the lines of force in an electromagnet.
2. How the amount of current through the magnet affects its strength.
3. How the number of turns of wire in the electromagnet affects its strength.
4. How the core material of an electromagnet affects its strength.

INFORMATION

Part Two of this lesson has four experiments that will prove some of the statements about electromagnetism made in Theory Lesson 10. By making a simple electromagnet and experimenting with it, you will see these principles work. Do the following experiments on a wooden bench or table; do not use a metal table.

EQUIPMENT NEEDED

Magnet wire
Nail
Two 1.5-volt cells
Compass
15-ohm resistor

EXPERIMENT 10-8

To learn the direction of the lines of force around an electromagnet.

Procedure.

Step 1. Unwind about one foot of magnet wire from the spool. Then wind 200 turns of the magnet wire around the nail in the direction shown in Fig. 10-10a. When you have finished winding, unwind about one foot more of wire, as shown in Fig. 10-10b, and cut the wire with your cutting pliers.

Step 2. Remove 1/2 inch of the insula-

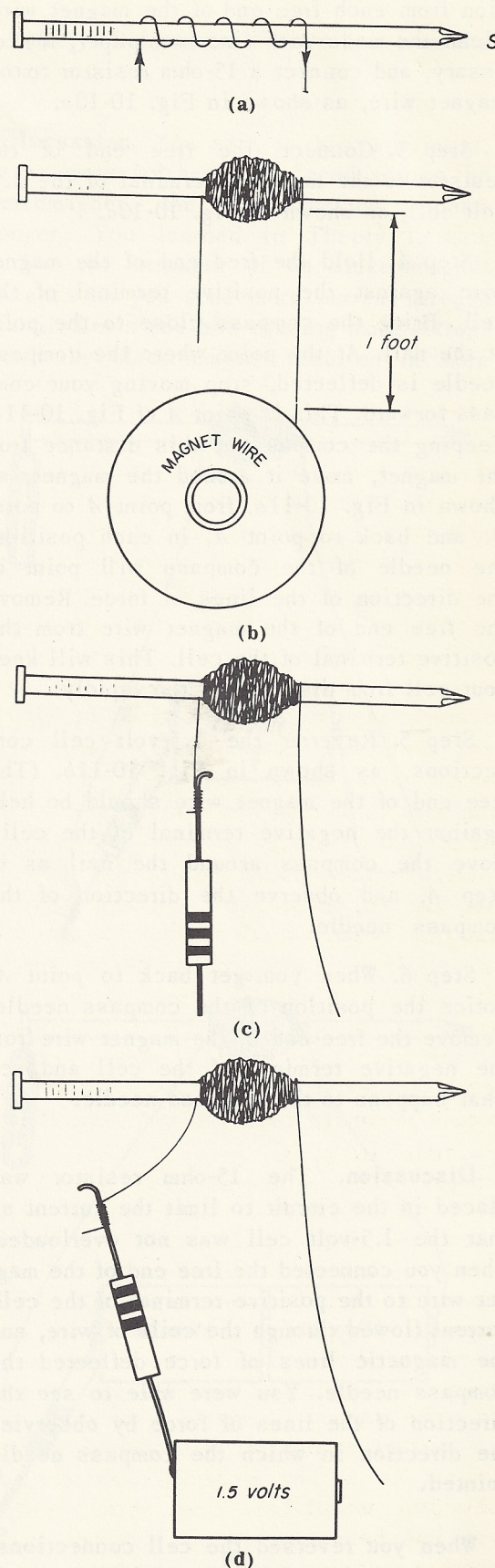


Fig. 10-10

from each free end of the magnet wire; rub the ends with fine sandpaper, if necessary, and connect a 15-ohm resistor to the wire, as shown in Fig. 10-10c.

3. Connect the free end of the magnet wire to the negative terminal of the 1.5-volt cell, as shown in Fig. 10-10d.

4. Hold the free end of the magnet wire against the positive terminal of the cell, bringing the compass close to the point of contact. At the point where the compass needle is deflected, stop moving your compass. This is point A of Fig. 10-11a. Move the compass at this distance from the magnet, move it around the magnet, as shown in Fig. 10-11a, from point A to point B and back to point A. In each position, the needle of the compass will point in the direction of the lines of force. Remove the free end of the magnet wire from the positive terminal of the cell. This will keep the cell from discharging too rapidly.

5. Reverse the 1.5-volt cell connections, as shown in Fig. 10-11b. (The free end of the magnet wire should be held against the negative terminal of the cell.) Move the compass around the nail as in Fig. 10-11b and observe the direction of the needle.

When you get back to point A, observe the position of the compass needle. Move the free end of the magnet wire from the negative terminal of the cell and see how it reacts to the compass needle.

Conclusion. The 15-ohm resistor was connected in the circuit to limit the current so the 1.5-volt cell was not overloaded. When the free end of the magnet wire was connected to the positive terminal of the cell, the current flowed through the coils of wire, and the magnetic lines of force deflected the compass needle. You were able to see the direction of the lines of force by observing the deflection of the compass needle.

When you reversed the cell connections, you observed that the lines of force were in

the opposite direction.

If you apply the left-hand rule you learned in Theory Lesson 10, you will see that your thumb points to the north pole. Therefore, you know the direction of the flux, since flux direction is from the north pole to the south pole.

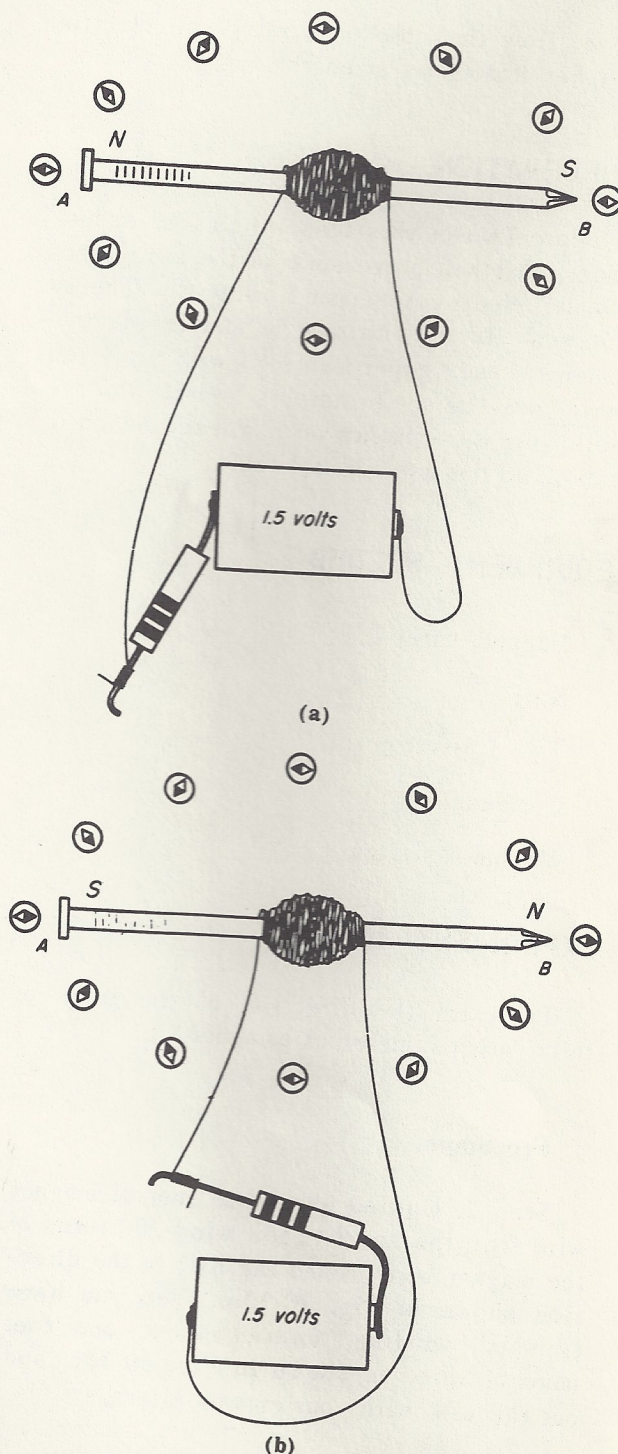


Fig. 10-11

When you disconnected one end of the magnet wire from the circuit, the compass needle no longer was deflected, because there was no current, and, therefore, no magnetic lines of force. In other words, an electromagnet can operate only when current is supplied to it, and it can be made to stop operating when current is cut off. A permanent magnet, on the other hand, is always a magnet. Electromagnets are very useful in electrical and radio circuits in which we want to have magnetism some of the time and no magnetism at other times. You will learn how we use electromagnetism in other ways when you study radio circuits in lessons to come.

EXPERIMENT 10-9

To learn how the amount of current flowing through the electromagnet affects its strength.

Procedure.

Step 1. Put a paper clip on the table on which you are working. Hold the electromagnet over the paper clip. Touch the free end of the magnet wire to the positive terminal of the 1.5-volt cell. Bring the magnet close enough to the paper clip to pick the clip up, as in Fig. 10-12a. Observe how close to the paper clip you must bring the magnet before the paper clip is attracted. If possible, measure the distance with a ruler. Remove the magnet wire from the negative terminal of the cell.

Step 2. Connect the negative terminal of a second 1.5-volt cell to the positive terminal of the cell you have been using. You now have a 3-volt battery connected to one end of your electromagnet.

Step 3. Holding the free end of the magnet wire against the positive terminal of the battery, try to pick up the paper clip, as shown in Fig. 10-12b. Observe how far from the paper clip the magnet is when it attracts the clip. Measure this distance, if possible. Remove the free end of the magnet wire from

the battery. Disconnect the resistor from the battery.

Discussion. You saw, in this experiment, that as more voltage was placed across the electromagnet, the electromagnet became stronger. You learned in Theory Lesson 10 that the strength of an electromagnet increases as you send more *current* through the coil. Let's see how placing more *voltage* across the electromagnet resulted in more

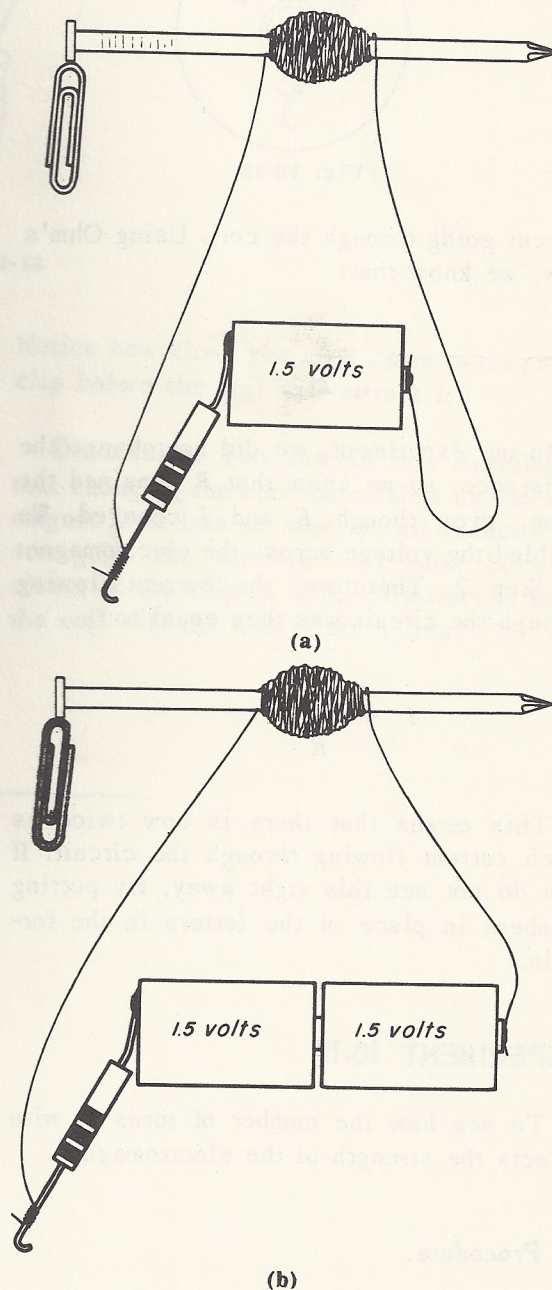


Fig. 10-12

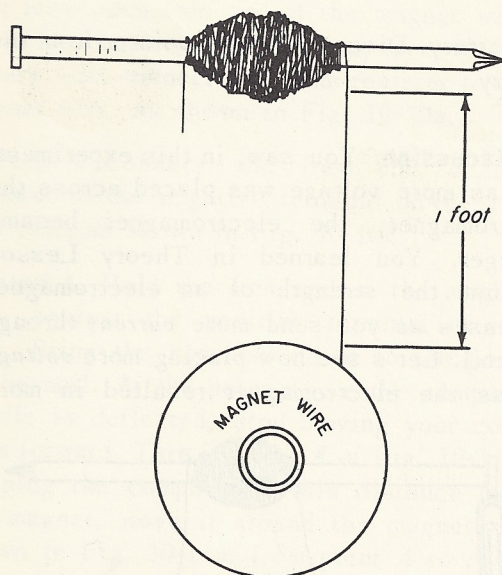


Fig. 10-13

current going through the coil. Using Ohm's Law, we know that:

$$I = \frac{E}{R}$$

In our experiment, we did not change the resistance, so we know that R remained the same, even though E and I changed. We doubled the voltage across the electromagnet in Step 2. Therefore, the current flowing through the circuit was then equal to:

$$I = \frac{2E}{R}$$

This means that there is now twice as much current flowing through the circuit. If you do not see this right away, try putting numbers in place of the letters in the formula.

EXPERIMENT 10-10

To see how the number of turns of wire affects the strength of the electromagnet.

Procedure.

Step 1. Splice one free end of the magnet

wire to the free end of the magnet wire on the spool and wind an additional 200 turns of wire around the nail in the same direction as the first 200 turns. (Don't worry if you lose count; one or two turns more or less do not affect this experiment.) Unwind one foot more of wire, as shown in Fig. 10-13, and cut the wire from the spool. Clean 1/2 inch of insulation from the free end and, if necessary, clean the free end with sandpaper. You now have a coil with 400 turns.

Step 2. Connect the free end of the 15-ohm resistor to the negative terminal of the three-volt battery.

Step 3. Hold the electromagnet over a paper clip and touch the free end of the magnet wire to the positive terminal of the battery. Observe how close you must bring the magnet to the paper clip before the clip is attracted. Measure this distance, if possible.

Step 4. Remove the free end of the magnet wire from the positive terminal of the battery.

Discussion. By doubling the number of turns on your electromagnet, you were able to make it about twice as strong. In Experiment 10-9, when the electromagnet had only 200 turns and was connected to the 3-volt battery, it had to be held close to the paper clip before it attracted the clip. With 400 turns, when the magnet was held about twice as far away from the clip as when it had 200 turns, it still was able to pick up the clip.

EXPERIMENT 10-11

To see how the core of an electromagnet affects its strength.

Procedure.

Step 1. Without unwinding the wire, remove the 400-turn coil from the nail by holding the coil with one hand to prevent the turns from loosening while you slip the nail

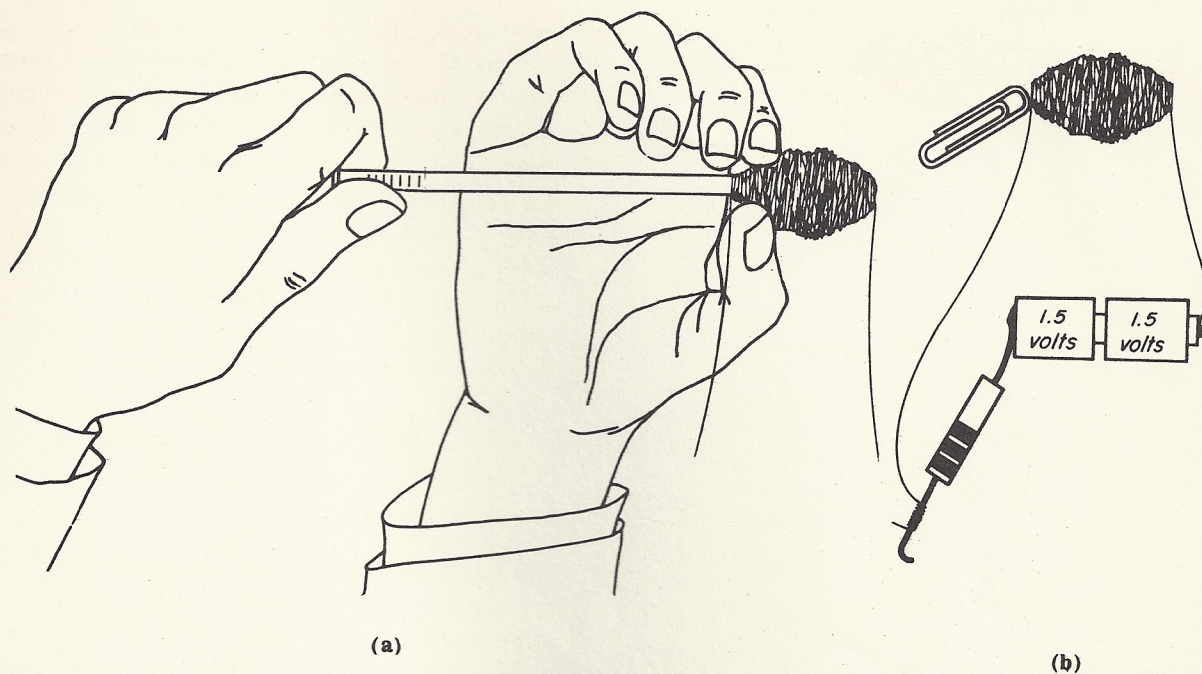


Fig. 10-14

out, as shown in Fig. 10-14a. It may be necessary to wiggle the nail back and forth to loosen it from the coil.

Step 2. Hold the coil over the paper clip and touch the free end of the magnet wire to the 3-volt battery, as shown in Fig. 10-14b.

Notice how close you must come to the paper clip before the coil will attract it.

Discussion. You saw in this experiment that changing the core material of an electromagnet from iron or steel to air reduces its strength. The air-core coil must be held closer to the clip in order to attract it than the coil with the iron or steel core.

